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# New threats for a protected plant: the need to review and update recovery plans of endangered species

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**Abstract.** *Helianthemum polygonoides* is a perennial halophyte described in 1987 in the Saltmarsh of Cordovilla (Albacete, SE Spain). In 2004 its distribution area was approximately 16 hectares, and its population was estimated at around 185000 adult individuals. Thus, this species is considered a local endemism due to its restricted distribution area, being catalogued as a "Critically Endangered" (CR) Atlas and Red Book of Threatened Vascular Flora of Spain. The main goal of this study is to review the current situation of the species, updating its distribution area and current threats and, consequently, establishing up-to-date conservation guidelines. A marked increment in the *H. polygonoides* population have been found (381909 individuals were estimated in 2022 census). We located new populations of *H. polygonoides*, increasing its core distribution area and revealing the accuracy of proposed protection measures. In this context, our results confirmed the direct relationship between the population size and the protection measures. According to the threat's assessment, we have observed that most of the threats and impacts have been reduced (e.g., grazing) or stopped (e.g., accumulation of debris). However, we have found new threats (e.g., rabbit proliferation, wild boar damages, and fires), emphasising the need to review and update the *H. polygonoides* Recovery Plan. In fact, we want to point out that mentioned threats are in constant change. We suggest the inclusion of new guidelines to control the newly-found threats and provide eight additional conservation proposals to improve the conservation status of the current populations of *H. polygonoides*.

**Keywords:** halophyte, saltmarsh, fragmentation, conservation.

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## Introduction

*Helianthemum polygonoides* Peinado, Mart. Parra, Alcaraz & Espuelas (Cistaceae) is a perennial chamaephyte, c. 10–30 cm tall, c. 10–50 cm diameter, suffruticose woody shrub. Regular yellow hermaphrodite flowers are disposed in racemes (4–10 flowers). Fruits are capsules with 4–6 seeds of around 1.5 mm in length (Erben, 1993; Copete *et al*., 2004). This halophyte was described in 1987 in the Saltmarsh of Cordovilla (Albacete, SE Spain) within the Special Areas of Conservation (SAC) "Saltmarsh of Cordovilla and Agramón and the Lagoon of Alboraj" (ES4210011) and the Natural Reserve of Cordovilla (which partially occupies the SAC; Anon., 2006), representing the single known population (Peinado *et al*., 1987; Copete *et al*., 2004). Its distribution area was approximately 16 hectares, and its population is estimated at around 185000 adult individuals (Ferrandis *et al*., 2004). Thus, this species was considered a local endemism due to its exclusivity in this area and its restricted distribution area. This endemism co-occurs with *Lygeum spartum* L. in elevated areas, occurring in zones free of vegetation (Ferrandis *et al*., 2004). This species mostly prefers poor soils, with a loamy-sandy texture, somewhat saline (Santiago González *et al*., 2022), with a low percentage of organic matter and moisture, as well as low ion exchange capacity (Moral *et al*., 1997). It should be noted that *H. polygonoides* could have a certain nitrophilic character, since it is very prone to develop along roadsides (Herranz *et al*., 1997).

Despite the SAC "Saltmarsh of Cordovilla and Agramón and the Lagoon of Alboraj" is one of the better-conserved saline habitats (EU Habitat 1420) (Espinar, 2009), it has suffered degradation processes due to anthropic activities which have affected a large area in recent decades (Ferrandis *et al.,* 2010). Habitat degradation has led to the current distribution of *H. polygonoides* and the alarming regression observed in its populations (Copete *et al*., 2004). Anthropic threats causing the regression were varied, highlighting (1) excavations for old gypsum extraction and construction of artificial waterways, (2) wastewater discharges, (3) channelling of dry riverbeds, (4) accumulation of debris and garbage, (5) agricultural activities, (6) grazing, and (7) the proliferation of urbanizations and communication routes (i.e., highways and rural roads) (Ferrandis *et al*., 2004). The urban nucleus (i.e., the municipality of Cordovilla) within the Saltmarsh of Cordovilla is also an enormous current threat to the conservation of this endemism (Ferrandis *et al*., 2011). Furthermore, previous studies have shown

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a population decline trend (Copete *et al*., 2009, Martínez-Duro *et al*., 2010), although a longer monitoring would be necessary to verify this conclusion (Copete *et al*., 2009). Ferrandis *et al.* (2011) estimated the area occupied by *H. polygonoides* c. 18 ha with c. 200000 individuals within a highly fragmented habitat. This study provided the more recent data about the species with data gathered in 2010. Therefore, the current situation of the conservation stage of *H. polygonoides* is unknown.

*Helianthemum polygonoides* is included in the Red List of Threatened Species of the International Union for Conservation of Nature (IUCN) since 2001, with the category of "Critically Endangered" (CR) for complying with criteria for reduced geographic distribution (B1ab(iii)+2ab(iii); IUCN 2012).The species is catalogued, according to these IUCN criteria in the Atlas and Red Book of Threatened Vascular Flora of Spain (Copete *et al*., 2004). Accordingly, the taxon was included in the Regional Catalogue of Endangered Species of Castilla-La Mancha (Anon., 1998), but inconsistently not in the National one (Anon., 2011). Hence, the main goal of this study was to review the current situation of the endemism *H. polygonoides* in the Saladar de Cordovilla (Albacete), performing censuses and evaluating trends in order to update its distribution area and current threats. Consequently, the obtained data will be used to establish up-to-date conservation guidelines.

## Materials and Methods

### Study site

The SAC, where *H. polygonoides* appears, harbours three peculiar habitats: (i) the saltmarsh of Cordovilla, located between the municipalities of Tobarra and Hellín (38º32'15' N, 1º36'40' W), (ii) the saltmarsh of Agramón, within the municipality of Hellín (38º25'08''N, 1º37'31''W), and (iii) the Lagoon of Alboraj, within the municipality of Tobarra (38º35'01''N, 1º39'09''W). They characterised by salinity gradients that determine the vegetation, being the best example of Spanish inland saltmarshes with a high species and habitats diversity (Cubero, 2015). Consequently, a wide variety of halophyte, halonitrophilic and gypsophilic plant species appears linked to its edaphic features, including endemic species such as *H. polygonoides* and several species *Limonium* (e.g., *L. tobarrense* J.Moreno, Terrones, M.A.Alonso, Juan & M.B.Crespo and *L. admirabile* Terrones, J.Moreno, M.Á.Alonso, Juan & M.B.Crespo) (Valdés *et al*., 1993; Moreno *et al*., 2018). Nonetheless, *H. polygonoides* populations only appears in the saltmarsh of Cordovilla and in the Lagoon of Alboraj, generally in small and scattered patches (Ferrandis *et al*., 2004). These ecosystems are highly vulnerable to anthropic factors (e.g., grazing, farming, or urban pressure) that notably provoke biodiversity loss and habitat fragmentation (Copete *et al*., 2004; Álvarez-Rogel *et al*., 2007; Ferrandis *et al*., 2011; Moreno *et al*., 2020).

### Census, map projection and threats detection

Eight studied areas were selected within the SAC and its surrounding areas, where Ferrandis *et al.* (2004) previously found *H. polygonoides* populations. These areas were divided into subzones defined as tessellas (i.e., when *H. polygonoides* participated in the potential vegetation within a studied area) (Table 1).

Table 1. Eight studied areas within the SAC "Saltmarshes of Cordovilla and Agramón and the Lagoon of Alboraj" and in the surrounding areas, indicating the numerical code of studied tessellas.

| N. | Area | Tessella |
|---|---|---|
| 1 | Tobarra | 1 |
| 2 | Aljubé | stand < 20m$^2$ |
| 3 | Water-treatment plant | 2 |
| 4 | Lagoon of Alboraj | 3 |
| 5 | Casa Siscar | 4-10 |
| 6 | Cordovilla | 11-25 |
| 7 | Prado Guerrero | 26-36 |
| 8 | Mora de Santa Quiteria | 37 |

Estimation censuses were carried out by installing randomly three plots of 25 m$^2$ in each studied tessella during April and May 2022. Within each plot, all mature individuals of *H. polygonoides* were counted as well as juvenile plants (i.e., plants of small dimensions in a state of incipient lignification) and dead individuals (i.e., rooted woody debris; Copete *et al*., 2009). In stands of less than 20 m$^2$, a direct count of the total number of mature plants was made (e.g., Aljubé area). The average density value (individuals/m$^2$) was calculated and, after multiplying it by the tessella surface, the total number of individuals was calculated. Besides, the standard deviation was calculated to quantify the dataset variability. The obtained information from estimated censuses was compared to Ferrandis *et al*. (2004) data, which used the same estimation census methodology in *H. polygonoides* populations. Data were tested for normality by Shapiro-Wilk test using the 'shapiro.test' function of the 'stats' package (R Core Team, 2023), and the variances between normal groups was compared using 'var.test' function of the 'stats' package (R Core Team, 2023). Student's t-Test was used to assess the differences between groups using 't.test' function of the 'stats' package (R Core Team 2023), being significance defined as $P \leq 0.05$. Statistical analyses were performed in R software version 4.1.1 (R Core Team, 2023).

A map projection was performed by exploring the *H. polygonoides* natural habitats in the field and using a global positioning satellite system Google Earth ™. The perimeter of the area of *H. polygonoides* distribution was traversed until a polygon was created and the Google Earth ™ provided information about its area. However, the area was not recorded when it was particularly small (i.e., less than 20 m$^2$) to avoid errors in Google Earth satellite readings, but it was marked on the map. This

information was used to update the maps provided by Ferrandis *et al.* (2004). ArcView GIS 3.2 software (ESRI, 1999) was used to the map creation after the incorporation into a GIS of the information collected in the field, using as a location format for the collection, representation and processing of the data UPS UTM and the map European Datum 1950 (N.O.U., 1975). This same methodology for the map projection of *H. polygonoides* distribution was used by Ferrandis *et al*. (2004).

Finally, signs and/or effects of disturbances and threats detected by Ferrandis *et al*. (2004) were verified in each tessella, and new ones were recorded in the field by personal observation. This information was used to analyze the conservation measures described in the *H. polygonoides* Recovery Plan (Herranz *et al*., 1997; Anon., 1999), and to assess their effectiveness according to the data obtained and their current threats.

## Results

### Distribution area of *H. polygonoides*

All populations of *H. polygonoides* were found within the SAC "Saltmarshes of Cordovilla and Agramón and the Lagoon of Alboraj" and the Natural Reserve "Saltmarshes of Cordovilla", except one located in the surroundings of Water-treatment plant area (Figure 1). The total area occupied by *H. polygonoides* was c. 15 Ha, showing the Tessellas 18 (Cordovilla area) and 33 (Prado Guerrero area) the largest surface area occupied by the species (i.e., 58084.1 and 42997.3 $m^2$ respectively; Appendix S1). Although significant differences in the total surface area occupied by *H. polygonoides* populations between 2004 and 2022 were not found ($P = 0.985$; Appendix S3), most of the smallest, isolated areas recorded in 2004 (i.e., Tobarra, Aljubé, Lagoon of Alboraj and Casa Siscar areas) were extinct since *H. polygonoides* individuals were not found (Appendix S2).

Overall, 381909 individuals were estimated for *H. polygonoides* in 2022 census (Appendices S1, S2), observing a significant increment of the total population respect to 2004 ($P = 0.027$; Appendix S3). The highest number of *H. polygonoides* individuals was found in the Tessellas 33 (Prado Guerrero area) and 18 (Cordovilla area) (i.e., 159950 and 87654 individuals, respectively; Appendix S1). In both tessellas, a remarkable increment was observed in comparison to 2004 census (Appendix S1).

Census comparisons by plant classes revealed that densities of mature individuals, juvenile plants, and dead individuals between 2004 and 2022 were significantly different ($P < 0.05$; Appendix S3). The highest numbers of mature plants per area were recorded in the Tessella 24 (Cordovilla area), with 4.1 individuals/$m^2$, and the Tessella 36 (Prado Guerrero area), with 3.9 individuals/$m^2$ (Appendix S1). In both cases, the densities of mature individuals increased respect to 2004 (Appendix S1). Similarly, the Tessellas 33 (Prado Guerrero area) and 24 (Cordovilla area) showed the highest numbers of juvenile plants per area (i.e., 2.2 and 1 individual/$m^2$, respectively; Appendix S1), although they decreased in both tessellas compared to 2004 census (Appendix S1). Regarding dead plants, only significant density values were found in the Tessella 18C (Cordovilla area), with 1.5 dead plants/$m^2$, and in the Tessella 31 (Prado Guerrero area), with 0.9 dead plants/$m^2$. In fact, the density of dead individuals in the Tessella 13 increased in comparison to the first census, while no estimate on dead plants was available for Tessella 18C at that time (Ferrandis *et al*., 2004) (Appendix S1). The density of dead individuals in the latter increased in comparison to 2004, but there was not available data from the former study in 2004 (Appendix S1).

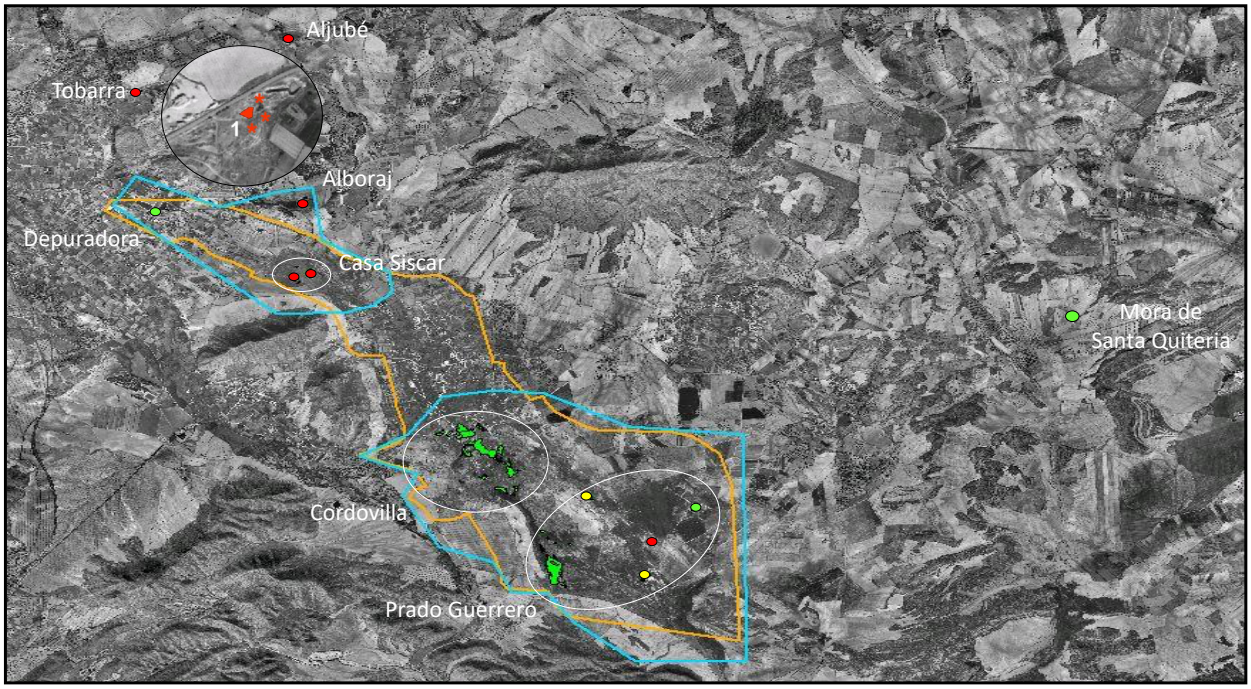


Figure 1. *Helianthemum polygonoides* distribution area. Scale 1:50.000.

## Current threats

In general, *H. polygonoides* populations were simultaneously threatened by several disturbances (Table 2). The most common threat was the presence of urbanizations, rural roads and highways, being a menace in every studied area (Table 2). Excavations and herbivory by rabbits and wild boar were also common threats in the studied areas (Table 2).

Threats and disturbances observed in the Cordovilla and Prado Guerrero areas were varied (Table 2). These areas were affected by artificial waterways, wastewater discharges, accumulation of debris and garbage, presence of urbanizations, rural roads and highways, remains of burned areas, water withdrawals for irrigation, excavations, herbivory by rabbits and wild boar, and use of phytosanitary products in crops (Table 2). Despite these existing threats, most of the habitat of *H. polygonoides* were in a good or acceptable state of conservation, since the main population centres of the species were found in the better-preserved areas (i.e. Cordovilla and Prado Guerrero areas). Nonetheless, it is due to the great habitat fragmentation of *H. polygonoides* that, generally, most of the stands of the distribution area were degraded, isolated or/and in a small tessellas.

Finally, it should be noted that in the Tobarra, Aljubé, Lagoon of Alboraj and Casa Siscar areas *H. polygonoides* individuals were not found in 2022. These areas were affected by wastewater discharges, accumulation of debris and garbage, presence of urbanizations, rural roads and highways, and negative effects of rabbits, wild boards, and phytosanitary products (Table 2).

Table 2. Threats and disturbances that affect *Helianthemum polygonoides* in the different areas of its distribution in 2004 and/or 2022 surveys. Grey colour indicates the type of threat/disturbance that negatively impacts each area. Numbers indicate distribution areas of Table 1.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Artificial waterways | | | | | | ■ | ■ | |
| Wastewater discharges | ■ | ■ | | ■ | | ■ | ■ | ■ |
| Debris and garbage | ■ | ■ | | | | ■ | ■ | |
| Urbanizations, rural roads, and highways | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Remains of burned areas | | | | | | ■ | ■ | |
| Grazing | | ■ | | | ■ | | | |
| Water withdrawals for irrigation | | | | | | ■ | ■ | |
| Excavations and herbivory (i.e., rabbits, wild boar) | ■ | ■ | ■ | ■ | | ■ | ■ | ■ |
| Use of phytosanitary products in crops | ■ | ■ | | ■ | | ■ | ■ | ■ |

## Discussion

### Assessment of the distribution area and population size of *H. polygonoides*

A marked increment in the *H. polygonoides* population have been found paradoxically accompanied by a slight reduction of the distribution area. The current distribution area of this endemism has been estimated at c. 15 Ha, being this value slightly lower than that provided Ferrandis *et al.* (2004). This pattern may be driven by the combined effects of the progressive accuracy of conservation measures and the extinction of satellite populations resulting from severe habitat fragmentation in the past. Thus, the decrement of the distribution area may be because increased intensity and expanding threats (i.e., high urban pressure, new rural roads and highways, and the constant activities of herbivores) which may lead to the definitive extinction of small, satellite populations in the early census, described as under extremely critical situation (Ferrandis *et al*., 2004, 2011). However, the core distribution area of *H. polygonoides* (e.g. Cordovilla stands) increased by the discovery of new populations (Figure 1). This fact may reveal the accuracy of protection measures within the context of the recent Natura 2000 Network implementation and the regional protected areas, which affects the main distribution stands of this species. Indeed, the Natural Reserve of the "Saltmarsh of Cordovilla" (Anon., 2006) and Natura 2000 Management Plan for the SAC "Saltmarshes of Cordovilla and Agramón and the Lagoon of Alboraj" (Anon., 2015) were approved within the lapse of both censuses compared in this study. Copete (2005) and Martínez-Duro *et al*. (2010) showed that *H. polygonoides* has an abundant seed bank (around 800 seeds/m$^2$ in the upper layer soil), being persistent at least 5 years and favouring the recruitment. Consequently, it can ensure the potential maintenance of populations. Besides, this endemism has a high colonizing character (Copete *et al*., 2004, 2012, present study) in its natural habitat, proliferating in open areas (e.g., roadsides or sewage treatment plant), when the plant cover is not destroyed by human activities or herbivores. This pattern was observed in Water-treatment plant and Prado Guerrero areas, where the distribution area of *H. polygonoides* increased in comparison to Ferrandis *et al*. (2004) data (Figure 1). This evidence demonstrates that the high colonizing rate and the persistent seed bank in the soil offer real possibilities of recovery. Furthermore, matrix models of population viability have demonstrated that the demographic bottleneck of *H. polygonoides* is in the abundance of mature individuals (i.e., age range

which will be only negatively affected if the habitat is destroyed) (Copete *et al*., 2009; Martínez-Duro *et al*., 2010). Those ecological features support our findings and contribute to understand the chorological and demographic trends of *H. polygonoides*.

In addition, the pioneering nature of *H. polygonoides* confirms that there is a direct relationship between the population size and the protection measures. The main species populations, large and well-formed ones, have a greater vigilance within the protected areas, maintaining and even increasing their demography. Conversely, isolated small peripherical populations and patches of *H. polygonoides*, are affected by habitat degradation, suffering local extinction. Thus, *H. polygonoides* populations in three small areas (i.e. Tobarra, Aljubé and Casa Siscar) have currently disappeared (Figure 1), being replaced by rainfed crops as Ferrandis *et al*. (2010) warned c. 10 years ago. Nonetheless, it should be noted that Mora de Santa Quiteria area, considered as an isolated small population of this endemism, has experienced a slight demographic increment. In this framework, it is evident that conservation management measures for a threatened species should be focused on the main populations, but this often leads to the discovery of small and isolated ones, which may hold interesting opportunities for the improvement of management measures, and thus should not be obviated in the conservation programs.

**Assessment of the threats of *H. polygonoides***

In the main areas of *H. polygonoides*, most of the threats and impacts that previously affected them (Ferrandis *et al*., 2004) have been reduced or removed because the effective application of conservation measures. A clear example of this is the absence of grazing, practically ceased in the *H. polygonoides* areas. Livestock has been currently reduced in comparison to a few decades ago (Copete *et al*., 2004; Ferrandis *et al*., 2004, 2010, 2011). The recovery of the ecosystem has been promoted by restrictions to anthropization. The abandonment of crops and the compliment of the conservation regulations in the protected natural environment have allowed not only the restoration of this habitat and its plant species but the fauna, observing an increment in the populations of birds of prey, wild boars and field rabbits (Ferrandis *et al*., 2011). Moreover, new human excavations (i.e., ditches) and accumulation of debris have been stopped in the studied area.

Nevertheless, our research has also showed the existence of new threats in the study area, which were not recorded by Ferrandis *et al*. (2004). The proliferation of the European rabbit (*Oryctolagus cuniculus* L.) in Castilla-La Mancha, as collateral effect of an effective conservation flora, is currently one of the most important problems in agriculture (Barrio *et al*., 2013; Delibes-Mateos *et al*., 2014), with a temporary hunting emergency being declared by caused damages (Anon., 2021). In the near future, this problem is expected to persist in the studied areas, so short-term measures focused on the control of rabbit populations would be necessary. Nonetheless, the most effective solutions in the long-term would be those based on the restoration of the functionality of the ecosystem (Catalán, 2010). Moreover, the high level of herbivory and the presence of excavations and burrows, as well as destruction by wild boar should be noted. Wild boars (*Sus scofra* L.) actively unearth roots of *H. polygonoides* in search of the hypogeal carpophores of *Terfezia* sp., which mycorrhize with the plant (Arenas *et al*., 2018; Morte *et al*., 2020). These negative factors have been observed in many habitat areas of *H. polygonoides*, highly affecting the endemic populations (present study).

Fire was other emerging threat in the habitat during the last decade. Many intentional forest fires were a consequence of the great social tension caused by the conflicts of interest between the Administration's conservation objectives and the owners of the land and residents of the nearby urban centres during the first years of the *H. polygonoides* Recovery Plan (Anon., 1999) implementation. These forest fires took place in summer-autumn 2011 and damaged part of the population of *H. polygonoides*. It is, therefore, necessary to update conservation measures to reduce the impacts exposed above. Our findings clearly demonstrate the need to review and update the casuistry of threatened species, since the conservation measures themselves can direct collaterally towards new impacts that must be managed and remedied in real time.

Conversely, there are areas (e.g., Tobarra and Aljubé) where the habitat of *H. polygonoides* has been dramatically affected and altered by human activities, being considered practically extinct (Ferrandis *et al*., 2010). These were small, isolated and degraded areas (i.e., satellite populations) so the conservation measures have come too late to restore damages. Currently, the mentioned areas are occupied by farms of typical dryland crops (e.g., olive and almond trees) (present study), favouring also the use of phytosanitary products in these crops to the population decline of *H. polygonoides* (e.g., Lagoon of Alboraj; present study).

**Evaluation of old conservation guidelines for *H. polygonoides***

The *H. polygonoides* Recovery Plan (Anon., 1999) was enacted to establish the appropriate conservation measures for its populations in order (1) to eliminate factors unfavourable to its maintenance and development; (2) to establish appropriate measures for the conservation of the habitat of *H. polygonoides* to suppress the responsible factors for the current detriment of its quality; and (3) to favour the expansion of the population *of H. polygonoides* within the Saltmarsh of Cordovilla through the reintroduction of the individuals in recently disturbed areas and the maintenance of new patches within the limits of its potential distribution area (Herranz *et al*., 1997). A periodical assessment of this Plan is preceptive and, according to the obtained results, the proposed conservation objectives and measures are reviewed and included in the Action Program, specifying the performed activities each year. We point

out that if in the case it would be necessary to modify the guidelines, they would have the same value and scope as the original ones.

Herranz *et al*. (1999) aimed to safeguard the endemic population of *H. polygonoides* and reduce threats. Partial success in protecting certain patches, with disappearance in some areas. Expansion objective partially achieved, but some tessellas vanished. Successful establishment of *ex situ* reserve at the Germplasm Bank. Periodic conservation status updates fulfilled, albeit not in the specified timeframe. Legal compliance overseen by environmental care service. Emerging threats suggest a need to update the sixth objective for an effective Recovery Plan. No evidence to gauge social groups' sensitivity to *H. polygonoides* conservation.

The Recovery Plan has slowed down some of the main threats and disturbances (e.g., the presence of rural roads inside the saltmarsh). Besides, the Plan has been effective to the reduction of grazing and to cease the conversion to irrigation of a large part of the saltmarsh, but we insist in the inclusion of the new threats to conserve properly *H. polygonoides* and its habitat.

## New conservation guidelines for *H. polygonoides*

On the basis of the previously supported evidence, we suggest eight new conservation measures in order to improve the conservation status of the current populations of *H. polygonoides* and, consequently, to enhance the protection of that plant endemism and its habitat:

1. It is necessary to include *H. polygonoides* within the Spanish Catalogue of Endangered Species, regulated by Royal Decree 139/2011, of 4th February, for the development of the List of Wild Species in Special Protection Regime and the Spanish Catalogue of Endangered Species (Anon., 2011).
2. It is necessary to enlarge the Microreserves of Flora to protect the population patches that remain outside the protected areas. For instance, of Laguna de Alboraj Micro-reserve is near the Water-treatment plant area, currently with no protection cover.
3. It would be convenient to keep several replicas of long-term conserved seeds in different germplasm banks. Currently, the Germplasm Bank of the Botanical Garden of Castilla-La Mancha is the only one that contains long-term conserved seeds of *H. polygonoides*.
4. It is necessary to establish a living collection of *H. polygonoides* in botanic gardens. It has not been possible so far (i.e., failed experiments in the Botanic Garden of Castilla-La Mancha; pers. obs.). There is evidence that the genus *Helianthemum* frequently mycorrhizes with fungi of the genus *Terfezia* (Dexheimer *et al*., 2011). Thus, we suggest determining which species of hypogeal fungi mycorrhizes with *H. polygonoides* and conserve mycelial or spore inoculum to mycorrhize the plants that could reproduce in the Botanic Garden of Castilla-La Mancha. Up to our knowledge, *H. polygonoides* does not hybrid with any other *Helianthemum* species. However, caution should be paid in the cultivation of living plant collections to avoid undesired hybridizations.
5. It is necessary to continue the demographic monitoring in order to detect long-term population trends and to review the status of their populations more frequently, as well as the conservation status of the habitat, to keep updated actions in the Conservation Plan.
6. To establish fences in the smallest population patches, which have lost individuals in recent years; and to signal the presence of this endemism with information panels, describing the importance of *H. polygonoides* and its conservation.
7. To develop ecological restoration programs to exclude the effects of different disturbances (e.g., excavations, channels, roads and rubble).
8. It is necessary to develop environmental education and dissemination programs aimed at different social groups in order to increase awareness of the importance of the conservation of both *H. polygonoides* and its habitat.

## Authorship Contribution

JM: Conceptualization, formal analysis, management of the project, methodology, supervision, writing; MJC: Conceptualization, writing; MPT: Conceptualization, writing; PF: Conceptualization, methodology, management of the project, supervision, writing.

## Conflict of interest

None.

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## Suplementary Material

**Appendix S1.** Average density values of *Helianthemum polygonoides* individuals in Cordovilla and Prado Guerrero areas according to mature, juvenile, and dead plant classes, indicating the standard deviation values between brackets.

**Appendix S2.** Average density values of *Helianthemum polygonoides* in Tobarra, Depuradora, Lagoon of Alboraj, Casa Siscar, and Mora de Santa Quiteria areas according mature, juvenile and dead plants, indicating the standard deviation values between brackets.

**Appendix S3.** Student's t-Test comparisons of area, total plants and density of mature, juvenile and dead plants of *Helianthemum polygonoides* populations between the database referred to 2004, belong to Ferrandis *et al*. (2004), and current provided data (2022).